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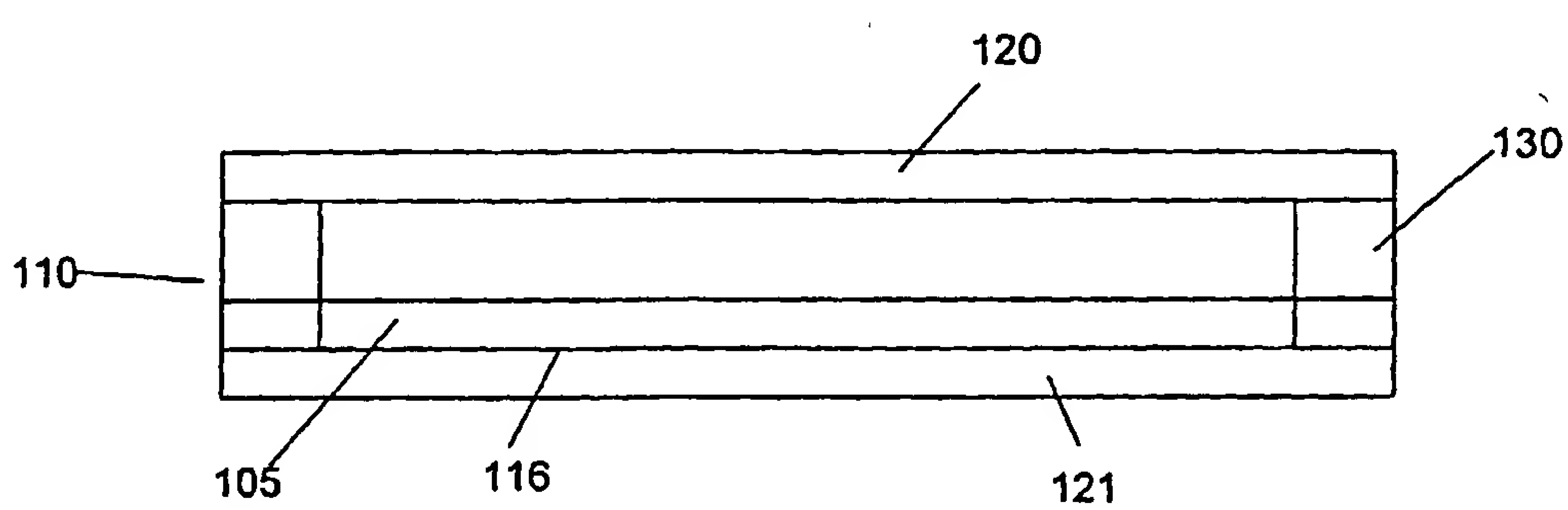
(54) Title: LAMINATES FOR ENCAPSULATING DEVICES



(57) Abstract: An encapsulation for an electrical device (105) is disclosed. The encapsulation comprises plastic substrates (120, 121) which are laminated onto the surface (116) of the electrical device (105). The use of laminated plastics is particularly useful for flexible electrical devices (105) such as organic LEDs.

WO 01/05205 A1

LAMINATES FOR ENCAPSULATING DEVICES

Field of the Invention

The present invention relates to the fabrication of devices. More particularly, the invention relates to packaging of devices.

Background of the Invention

In device fabrication, one or more device layers are formed on a substrate. The layers are sequentially deposited and patterned to create features on the surface of the substrate. The layers can be patterned individually and/or as a combination of layers to form the desired features. The features serve as components that perform the desired functions, creating the device.

One type of device which is of particular interest is a light emitting diode (LED). LEDs can have a variety of applications. For example, a plurality of LED cells or pixels can be formed on a substrate to create a pixelated LED device for use as a display, such as a flat panel display (FPD) for telephones, computer displays, TV screens and the like.

Typically, an LED pixel comprises one or more functional layers sandwiched between two electrodes to

form a functional stack. Charge carriers are injected from both electrodes. These charge carriers recombine in the functional layer or layers, causing visible radiation to emit. Recently, significant advances have been made utilizing organic functional layers to form organic light emitting diodes (OLEDs).

OLED pixels are very sensitive to the environment. Exposure to moisture and/or air causes rapid degradation of the OLED, creating reliability problems. Some of the substances used to build the layers are sensitive organic compounds and some reactive metals like Calcium and Magnesium. These materials are extremely susceptible to damage caused by oxidation in the presence of oxygen and/or moisture. Thus, a package which adequately protects the OLED from the environment is needed. Further, the package should be cost effective and conducive to high throughput to reduce the overall manufacturing cost and time.

Summary of the Invention

The invention relates to packaging of a device. In accordance with the invention, the device is package using a laminate. In one embodiment, laminates are placed on the top and bottom of a device. The laminates

are pressed against the device and heated to activate a sealant which causes the laminates to adhere to the device. In one embodiment, the laminate is pressed against the device and heated using rollers.

Brief Description of the Drawings

Fig. 1 shows an embodiment of the invention;

Fig. 2 shows an laminate for encapsulating an electrical device in accordance with one embodiment of the invention; and

Figs. 3-5 illustrate a process for encapsulating an electrical device.

Preferred Embodiments of the Invention

The invention relates generally to the fabrication of devices. In particular, the invention provides a cost effective package for encapsulating devices, particularly those formed on flexible or thin substrates.

Fig. 1 shows a cross section of a device 110 in accordance with one embodiment of the invention. The device can be, for example, electrical, mechanical, or electromechanical. Microelectromechanical systems (MEMS) are also useful. The device comprises one or

more active components formed on a substrate. The active components provide the desired electrical and/or mechanical functions.

To reduce the overall thickness of the device, the active components can be formed on a thin substrate, such as less than 0.3 mm thick. Forming the active components on a thin flexible substrate is also useful to provide a flexible device. The substrate comprises, for example, plastic, polymer, silicon, ceramic, glass, or quartz glass. Other types of substrates, such as semiconductor substrates are also useful. The thin substrate should provide adequate mechanical integrity to support the components during and after processing. Typically, the thin substrates are about 20 - 300 um.

In one embodiment, the device 101 comprises an electrical device, such as a pixelated OLED device. Terminals or pins (not shown) which enable electrical connections to the active components are provided. OLED devices are described in, for example, United States Patent 4,720,432 and Burroughes et. al, Nature 347 (1990) 539, which are herein incorporated by reference for all purposes. The pixels of the OLED device can be arranged to form an FPD. FPDs are used in various consumer electronic products, including cellular

phones, cellular smart phones, personal organizers, pagers, advertising panel, touch screen displays, teleconferencing equipment, multimedia equipment, virtual reality products, and display kiosks. In one embodiment, the organic LED device comprises a flexible substrate to provide bending, creating, for example, a flexible FPD.

The OLED pixels are materials formed on a substrate 105. In one embodiment, the substrate comprises a transparent substrate and serves as the display surface. The substrate is prepared to support a laminate 120. For example, supports 150 are provided surrounding the OLEDs to support the laminate. The laminate covers the device and hermetically seals the components, protecting them from the environment. The device can also include support posts (not shown) in the non-active regions to provide support for the laminate. This prevents the laminate from collapsing onto the components and affecting the device's functionality. Support posts are particularly useful for flexible devices. Providing support posts in non-active regions the device is described in co-currently filed International Patent Application titled "Encapsulation of a Device" (attorney

docket number 99E 1975), which is herein incorporated by reference for all purposes.

A second laminate 121 can be provided to cover the opposite side 116 of the device. As shown, the opposite side comprises the bottom surface of the substrate. The second laminate seals the substrate, preventing the diffusion of air and/or moisture. The laminate can also protect the organic display surface from, for example, scratches. To provide visibility to the display, a transparent laminate is used.

In one embodiment, the laminate comprises a flexible material. The flexible laminate is particularly useful with flexible devices, such as those formed on a flexible substrate. Depending on the optical requirements, a transparent or opaque laminate can be used. For example, the display side of the organic OLED device is encapsulated with a transparent laminate. As for the non-display side, the optical characteristics of the laminate is not important.

A sealant is used to attach the laminate on the device, sealing the components to protect them from moisture and air. The sealant, in one embodiment, can flow at a given temperature (activation temperature) to ensure complete sealing of the device. The activation

temperature of the sealant should be sufficiently low enough to avoid damaging the components of the device.

Fig. 2 shows a laminate 200 for encapsulating the device in accordance with one embodiment of the invention. As shown, the stack comprises a laminate substrate 210. The laminate substrate preferably comprises a material with sufficient thermal stability to maintain its mechanical integrity during the adhesion process. The thickness of the laminate substrate depends on the substrate material. Typically, the laminate substrate is about 10 - 400 µm thick. The thickness of the laminate substrate should be as thin as possible to reduce the overall device thickness.

In one embodiment, the substrate comprises a flexible material, such as a plastic film. Various commercially available plastic films are useful. Such films, for example, include transparent poly(ethylene terephthalate) (PET), poly(butylene terephthalate) (PBT), poly(enthylene naphthalate) (PEN), Polycarbonate (PC), polyimides (PI), polysulfones (PSO), and poly(*p*-phenylene ether sulfone) (PES). Other films such as polyethylene (PE), polypropylene (PP), poly(vinyl chloride) (PVC), polystyrene (PS) and poly(methyl methyleacrylate) (PMMA) can also be useful.

A barrier layer 220 is formed on the surface of the substrate to prevent the diffusion of oxygen and/or moisture, thereby protecting the device. The use of the barrier layer can be avoided if the substrate material can prevent the diffusion of oxygen and/or moisture. Preferably, the barrier is formed on the inner surface (surface facing the device) of the laminate. As such, the substrate protects the barrier layer from damage. The thickness of the barrier should be sufficient to prevent diffusion of oxygen and/or moisture. For flexible applications, the barrier layer should be as thin as possible so as not to hinder the flexibility of the device. Typically, the thickness of the barrier layer is about 5 - 5000 nm. In one embodiment, barrier layers are coated on both sides for more efficient protection.

In one embodiment, the barrier layer comprises a metallic film such as copper or aluminum. Other materials which can serve as an oxygen and/or moisture barrier, such as ceramic, are also useful. A barrier comprising multiple of different barrier material layers is also useful. The metallic barrier layer can be coated on the substrate by various deposition techniques such as thermal evaporation, sputtering, chemical vapor

deposition (CVD), or plasma enhanced CVD (PECVD). Alternatively, the barrier film can be glued or laminated directly to the substrate surface. For transparent applications, the barrier layer can comprise a dielectric material such as silicon monoxide (SiO), silicon oxide (SiO_x), silicon dioxide (SiO_2), silicon nitride (Si_xN_y), or metal oxide such as aluminum oxide (Al_2O_3). Other dielectric materials which prevent the diffusion of oxygen and/or moisture are also useful to serve as a barrier layer. The dielectric barrier layer can be formed on the substrate by various deposition techniques such as thermal oxidation, CVD, or PECVD.

A sealant or adhesive layer 230 is provided above the barrier layer. The sealant layer provides adhesion to the surface of the electrical device when compressed under heated conditions. Preferably, the sealant should be activated at an elevated temperature, causing the laminate to adhere to the surface of the device and sealing the components. To ensure good sealing between the laminate and the device, the sealant should flow slightly at the activation temperature. The activation temperature should be below that which damages the device, such as altering the chemistry and/or physics of the active components. Preferably, the activation

temperature of the sealant is as low as possible. For example, the activation temperature is about 80 - 140°C.

In one embodiment, the sealant is a hot melt type adhesive. Polymer mixtures which can include different polymers and/or additives are also useful. Preferably, the sealant comprises ethylene vinyl acetate resins, ethylene ethyl acrylate resins. Other types of sealant, such as low-density polyethylene, copolymers including ethylene-vinyl acetate resins, ethylene-ethyl acrylate resins are also useful. The sealant can be coated on the surface of the laminate using conventional techniques.

Optionally, a protective layer 240 can be formed on the outer surface of the laminate. The protective layer comprises, for example, polymeric resin that serves as a hard coating that protects the substrate from being scratched. Alternatively, an adhesive layer can be formed on the outer surface of the substrate for further processing, such as adhering additional layers thereon. These additional layers can include, for example, color filters, polarizers, or anti-glare films.

Figs. 3-5 show a process for encapsulating a device in accordance with one embodiment of the invention. Referring to Fig. 3, a device 301 is shown. The device,

for example, comprises a pixelated OLED device. Other electrical devices, such as sensor arrays or MEMS, are also useful. Preferably, the device is formed on a flexible or thin substrate.

A first laminate 310 is placed over the device to cover the active components. If necessary, a second laminate 320 is placed on the bottom surface of the device. Depending on the optical requirements, the laminates can be transparent or opaque. For example, a transparent laminate is used on the display surface of the OLED device. The inner surface of the laminates comprises a sealant for sealing the laminate to the surfaces of the device.

Referring to Fig. 4, a laminating tool 401 is provided. The laminating tool, for example, comprises first and second rollers 420 and 425. The rollers can be made of rubber. Other materials such as silicon can also be used. During operation, the rollers are heated and rotated. The rollers rotate in opposite directions, as indicated by the arrows, to pull the device 301 with the laminates thereon through the rollers.

As the device is pulled through the rollers, the laminates are heated and compressed onto the surfaces of the device. The pressure exerted by the rollers should

be sufficient to facilitate sealing without crushing or damaging the device. Typically, the pressure exerted by the rollers is about 1 - 500 kN/m^2. The laminates are heated to a temperature above the activation temperature of the sealant. The process temperature should be maintained as low as possible, for example, slightly above the sealant's activation temperature. The speed of the rollers can be adjusted to ensure complete sealing of the laminates onto the device.

Referring to Fig. 5, after the device is pulled through the rollers, the encapsulation process is completed to form the device 500 as shown. The present invention, as described, performs encapsulation of the device in an environment free of any evaporable chemicals. This is advantageous as the possibility of corrosion of the active components from chemicals are avoided, thereby improving yields. Further, the encapsulation process can be modified to provide continuous and parallel processing to increase throughput and decrease raw process time. For example, large laminates can be used to sandwich a plurality of devices therebetween. The laminates than are processed through the rollers, encapsulating a plurality of

devices. The devices can then be separated after encapsulation.

While the invention has been particularly shown and described with reference to various embodiments, it will be recognized by those skilled in the art that modifications and changes may be made to the present invention without departing from the spirit and scope thereof. The scope of the invention should therefore be determined not with reference to the above description but with reference to the appended claims along with their full scope of equivalents.

What is claimed is:

1. A device comprising:

a substrate;

at least one active component formed on a top surface of the substrate; and

a first laminate over the top surface of the substrate, encapsulating the device.

2. The device of claim 1 wherein the device comprises an OLED device.

3. The device of claim 2 wherein the substrate supports the active component.

4. The device of claim 3 wherein the substrate comprises a flexible substrate.

5. The device of claim 4 wherein the substrate material is selected from a group of materials consisting of polymer, glass, ceramic, or semiconductor material.

6. The device of claim 3 wherein the substrate comprises a transparent substrate.

7. The device of claim 6 wherein the substrate material is selected from a group of materials consisting of polymer or glass.

8. The device of claim 3 wherein the substrate comprises a flexible transparent substrate.

9. The device of claim 8 wherein the substrate comprises a material selected from a polymer or glass.

10. The device of claim 1 wherein the substrate supports the active component.

11. The device of claim 10 wherein the substrate comprises a flexible substrate.

12. The device of claim 11 wherein the substrate material is selected from a group of materials consisting of polymer, glass, ceramic, or semiconductor material.

13. The device of claim 10 wherein the substrate comprises a transparent substrate.

14. The device of claim 13 wherein the substrate material is selected from a group of materials consisting of polymer or glass.

15. The device of claim 10 wherein the substrate comprises a flexible transparent substrate.

16. The device of claim 15 wherein the substrate comprises a material selected from a polymer or glass.

17. The device of claim 6, 7, 8, 9, 13, 14, 15,or 16 further comprises a second laminate on a bottom surface of the substrate, wherein the second laminate comprises a transparent laminate.

18. The device of claim 17 wherein the laminates comprises:

a laminate substrate; and

a sealant on a surface of the laminate substrate that contacts the device.

19. The device of claim 18 wherein the laminate substrate comprises a material having a sufficient

thermal stability to maintain mechanical integrity during processing.

20. The device of claim 19 wherein the laminate substrate comprises a plastic material.

21. The device of claim 20 wherein the plastic laminate substrate is selected from poly(ethylene terephthalate), poly(butylene terephthalate), poly(enthylene naphthalate), polycarbonate, polyimides, polysulfones, poly(*p*-phenylene ether sulfone), polyethylene, polypropylene, poly(vinyl chloride), polystyrene, or poly(methyl methyleacrylate).

22. The device of claim 21 wherein the sealant comprises an activation temperature which causes the sealant to flow to ensure good sealing between the laminate and the device.

23. The device of claim 22 wherein the activation temperature is below a temperature which damages the device.

24. The device of claim 23 wherein the laminate comprises a barrier layer on the laminate, the barrier layer inhibits the diffusion of air or moisture.

25. The device of claim 24 wherein the barrier layer comprises a material selected from a group consisting of a metallic or a dielectric material.

26. The device of claim 25 wherein the metallic material comprises copper or aluminum and dielectric material comprises silicon monoxide, silicon oxide, silicon dioxide, silicon nitride (Si_2N_4), or a metal oxide.

27. The device of claim 26 wherein the sealant comprises an activation temperature which causes the sealant to flow to ensure good sealing between the laminate and the device.

28. The device of claim 27 wherein the activation temperature is below that which damages the device.

29. The device of claim 18 wherein the laminate comprises a barrier layer on the laminate, the barrier layer inhibits the diffusion of air or moisture.

30. The device of claim 29 wherein the barrier layer comprises a material selected from a group consisting of a metallic or a dielectric material.

31. The device of claim 3, 4, 5, 10, 11 or 12 further comprises a second laminate on a bottom surface of the substrate.

32. The device of claim 31 wherein the laminates comprises:

a laminate substrate; and

a sealant on a surface of the laminate substrate that contacts the device.

33. The device of claim 32 wherein the laminate substrate comprises a material having a sufficient thermal stability to maintain mechanical integrity during processing.

34. The device of claim 33 wherein the laminate substrate comprises a plastic material.

35. The device of claim 34 wherein the plastic laminate substrate is selected from poly(ethylene terephthalate), poly(butylene terephthalate), poly(enthylene naphthalate), polycarbonate, polyimides, polysulfones, poly(*p*-phenylene ether sulfone), polyethylene, polypropylene, poly(vinyl chloride), polystyrene, or poly(methyl methyleacrylate).

36. The device of claim 35 wherein the sealant comprises an activation temperature which causes the sealant to flow to ensure good sealing between the laminate and the device.

37. The device of claim 36 wherein the activation temperature is below a temperature which damages the device.

38. The device of claim 37 wherein the laminate comprises a barrier layer on the laminate, the barrier layer inhibits the diffusion of air or moisture.

39. The device of claim 38 wherein the barrier layer comprises a material selected from a group consisting of a metallic or a dielectric material.

40. The device of claim 39 wherein the metallic material comprises copper or aluminum and dielectric material comprises silicon monoxide, silicon oxide, silicon dioxide, silicon nitride (Si_2N_4), or a metal oxide.

41. The device of claim 32 wherein the sealant comprises an activation temperature which causes the sealant to flow to ensure good sealing between the laminate and the device.

42. The device of claim 41 wherein the activation temperature is below that which damages the device.

43. The device of claim 32 wherein the laminate comprises a barrier layer on the laminate, the barrier layer inhibits the diffusion of air or moisture.

44. The device of claim 43 wherein the barrier layer comprises a material selected from a group consisting of a metallic or a dielectric material.

45. The device of claim 2, 3, or 10 wherein the laminate comprises:

a laminate substrate; and

a sealant on a surface of the laminate substrate that contacts the device.

46. The device of claim 45 wherein the laminate substrate comprises a material having a sufficient thermal stability to maintain mechanical integrity during processing.

47. The device of claim 46 wherein the sealant comprises an activation temperature which causes the sealant to flow to ensure good sealing between the laminate and the device.

48. The device of claim 47 wherein the laminate comprises a barrier layer on the laminate, the barrier layer inhibits the diffusion of air or moisture.

49. The device of claim 45 wherein the sealant comprises an activation temperature which causes the sealant to flow to ensure good sealing between the laminate and the device.

50. The device of claim 45 wherein the laminate comprises a barrier layer on the laminate, the barrier layer inhibits the diffusion of air or moisture.

51. In the fabrication of a device, a method for packaging the comprising:

providing a device comprising a substrate having at least one active component formed on a top surface thereof;

placing a laminate on the top surface of the substrate; and

pressing the laminate against the device to activate a sealant which causes the laminate to adhere to the device.

52. The method of claim 51 wherein the device comprises an OLED.

53. The method of claim 52 wherein the substrate comprises a material selected from polymer or glass.

54. The method of claim 51 wherein the device comprises a flexible OLED.

55. The method of claim 54 wherein the substrate comprises a material selected from polymer or glass.

56. The method of claim 51 wherein the device comprises a flexible device.

57. The method of claim 51, 52, 53, 54, 55, or 56 further comprises placing a second laminate on a bottom surface of the device, wherein the pressing activates the sealant to cause the laminates to adhere to the device.

58. The method of claim 57 wherein the sealant is located on the inner surface of the laminates that contacts the device.

59. The method of claim 58 further comprises heating the laminate to activate the sealant.

60. The method of claim 59 wherein heating the laminate causes the sealant to flow.

61. The method of claim 60 wherein pressing the laminates comprises passing the device with the laminate through rollers that presses the laminates against the device.

62. The method of claim 61 wherein the rollers heat the laminates to activate the sealant.

63. The method of claim 62 wherein the laminate comprises a barrier layer.

64. The method of claim 63 wherein the barrier inhibits the diffusion of air or moisture.

65. The method of claim 64 wherein the laminates comprises flexible laminates.

66. The method of claim 58 wherein pressing the laminates comprises passing the device with the laminate

through rollers that presses the laminates against the device.

67. The method of claim 66 wherein the rollers heat the laminates to activate the sealant.

68. The method of claim 67 wherein heating the laminate causes the sealant to flow.

69. The method of claim 68 wherein the laminates comprises flexible laminates.

70. The method of claim 62 wherein the laminate comprises a barrier layer.

71. The method of claim 51, 52, 53, 54, 55, or 56 wherein the sealant is located on the inner surface of the laminates that contacts the device.

72. The method of claim 71 further comprises heating the laminate to activate the sealant.

73. The method of claim 72 wherein heating the laminate causes the sealant to flow.

74. The method of claim 73 wherein pressing the laminates comprises passing the device with the laminate through rollers that presses the laminates against the device.

75. The method of claim 74 wherein the rollers heat the laminates to activate the sealant.

76. The method of claim 75 wherein the laminate comprises a barrier layer.

77. The method of claim 76 wherein the laminates comprises flexible laminates.

78. The method of claim 71 wherein pressing the laminates comprises passing the device with the laminate through rollers that presses the laminates against the device.

79. The method of claim 78 wherein the rollers heat the laminates to activate the sealant.

80. The method of claim 79 wherein heating the laminate causes the sealant to flow.

81. The method of claim 80 wherein the laminates comprises flexible laminates.

82. The method of claim 71 wherein the laminate comprises a barrier layer.

83. The method of claim 51 wherein pressing the laminate comprises passing the device with the laminate through rollers that presses the laminate against the device.

84. The method of claim 83 wherein the rollers heat the laminate to activate the sealant.

85. The method of claim 84 wherein heating the laminate causes the sealant to flow.

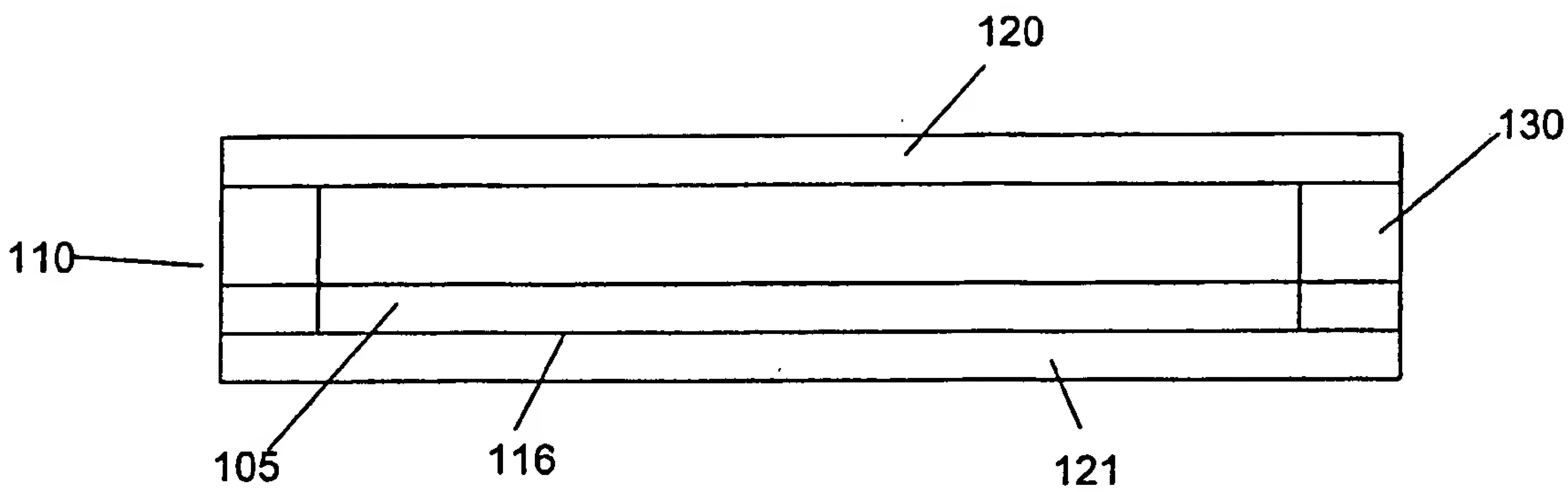


Fig. 1

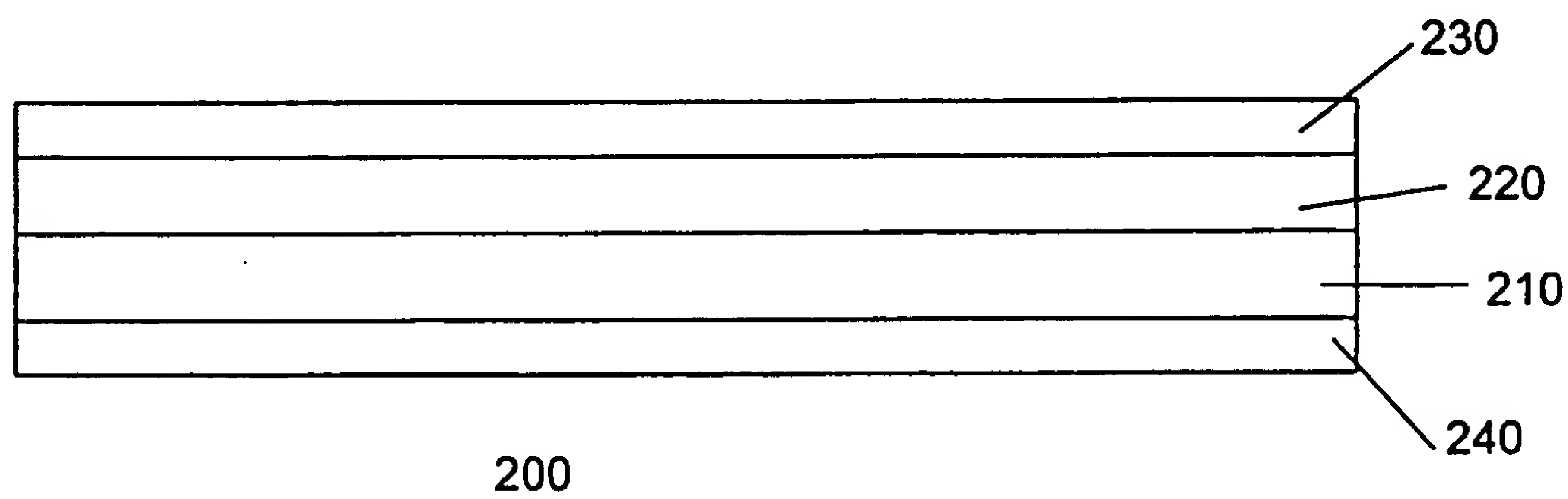


Fig. 2

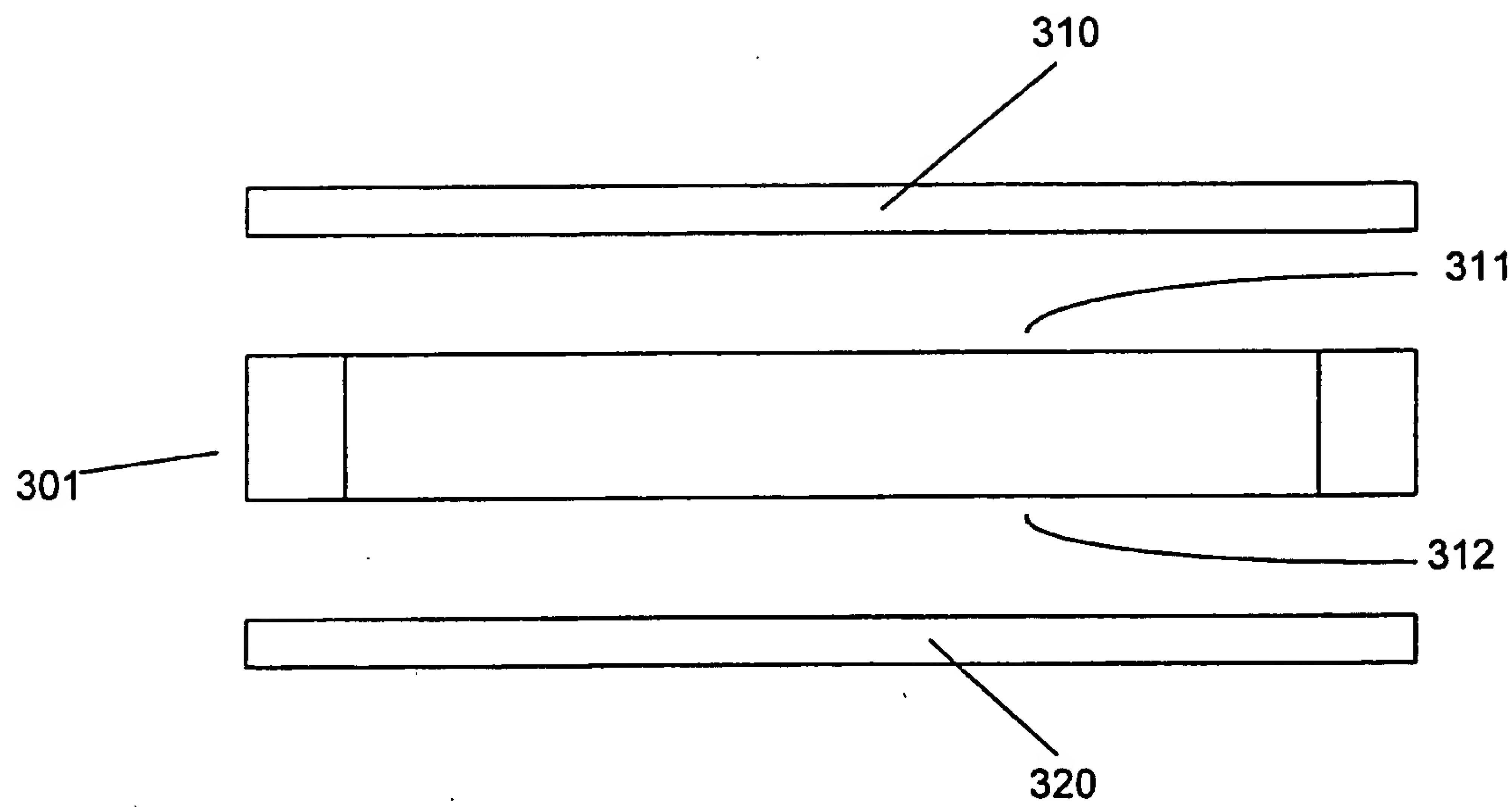


Fig. 3

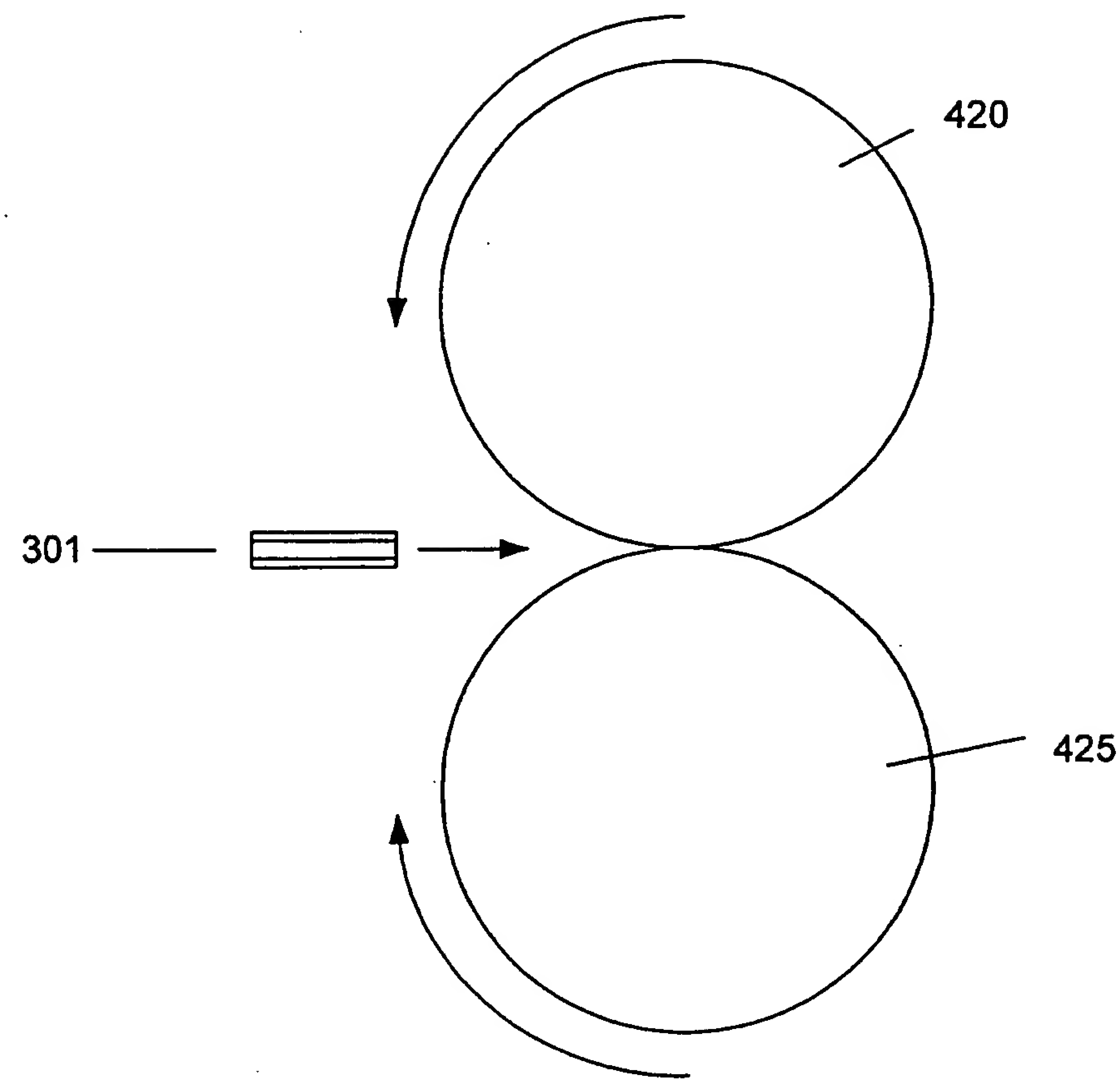


Fig. 4

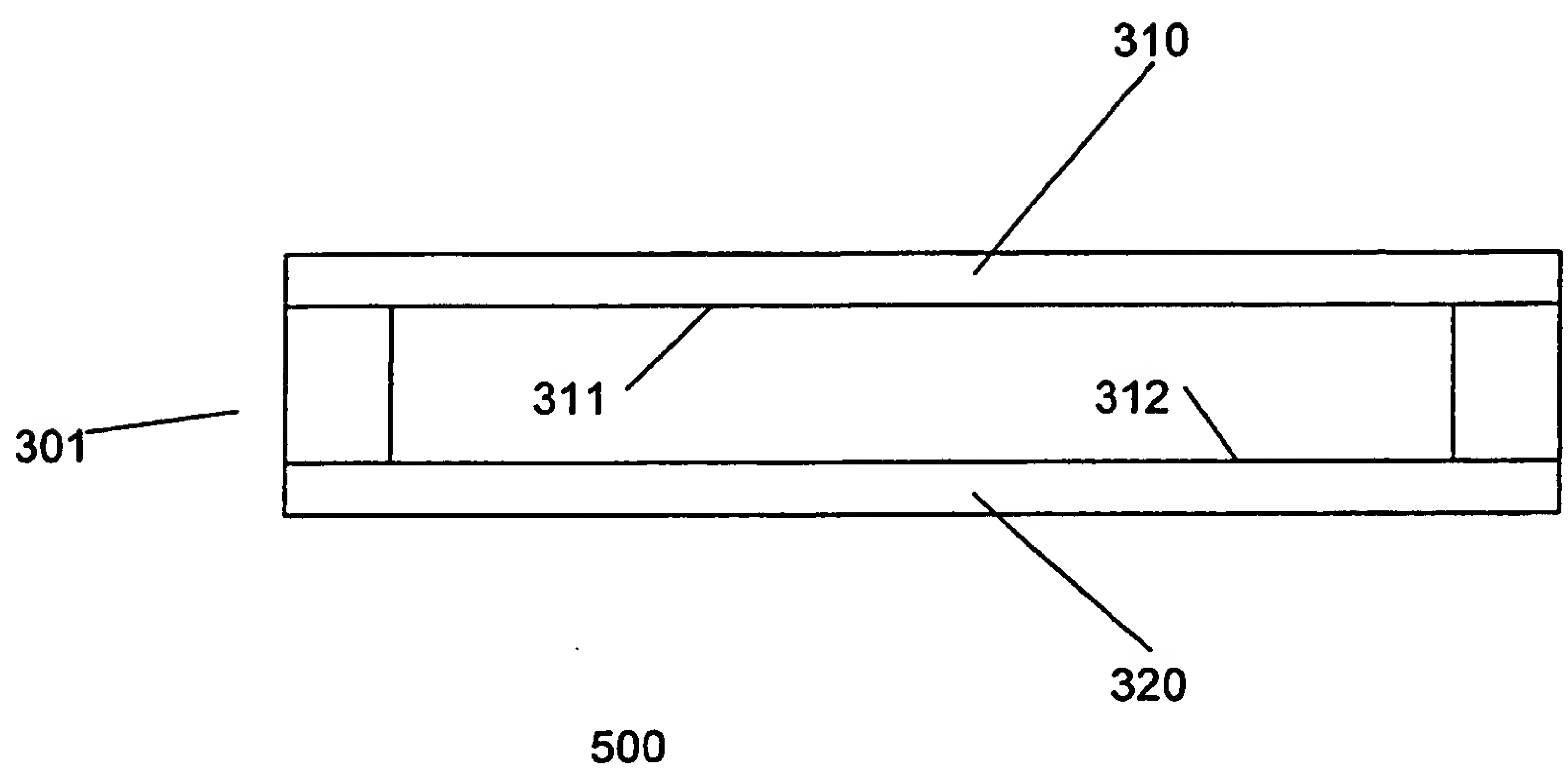


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG 99/00070

A. CLASSIFICATION OF SUBJECT MATTER

IPC⁷: H05K 5/02, 5/06; H01L 23/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC⁷: H01L 23/28; G06K 19/077; H05K 5/02, 5/06; H05B 33/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 4767679A (KAZUHIKO K.) 30 August 1988 (30.08.88), abstract and summ. of invention, fig.1.	1-3, 6-7, 10, 13, 14, 51-53 4-5, 8-9, 11-12, 15-50, 54-85
X Y	US 4746392 A (HOPPE J.) 24 May 1988 (24.05.88), abstract and summ. of of invention, fig. 3.	1, 51 4-5, 8-9, 11-12, 15-50, 54-85
Y A	GB 2028719 A (KODAK E.) 12 March 1980 (12.03.80), abstract and fig.2	61-70, 74-81, 83-85 1-60, 71-73, 82

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
„A" document defining the general state of the art which is not considered to be of particular relevance
„E" earlier application or patent but published on or after the international filing date
„L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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„P" document published prior to the international filing date but later than the priority date claimed
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„X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
„Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
„&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 April 2000 (07.04.00)	20 June 2000 (20.06.00)

Name and mailing adress of the ISA/AT	Authorized officer
Austrian Patent Office Kohlmarkt 8-10; A-1014 Vienna Facsimile No. 1/53424/200	Koskarti Telephone No. 1/53424/326

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
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